

**A NOVEL CHARGE LEAKAGE CORRECTION CIRCUIT
FOR APPLICATIONS IN PLLS**

BACKGROUND OF THE INVENTION

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Field of the Invention

The present invention relates generally to Phased Locked Loops (PLLs) and, more particularly, to charge correction for a PLL filter.

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Description of the Related Art

Phased Locked Loops (PLLs) are common components utilized in a variety of applications. For example, Frequency Modulation (FM) and Amplitude Modulation (AM) modulators utilize PLLs. PLLs operate by locking onto a phase and frequency of an input signal through continual adjustment of an oscillator. The PLL oscillator can be current or voltage driven. Typically, though, the PLL oscillator is a Voltage Controlled Oscillator (VCO).

Referring to FIGURE 1 of the drawings, the reference numeral 100 generally designates a conventional PLL. A conventional PLL comprises a Phase-Frequency Detector (PFD) 102, a charge pump 104, a Low Pass Filter (LPF) 106, a VCO 108, and a frequency divider 110.

The illustration of the components of the PLL, though, do not necessarily lend to a complete explanation. The LPF 106 further comprises a capacitor 116 and a resistor 118

which operated on the principle of capacitive impedance where impedance of a capacitor is inversely proportional to the signal frequency. Also, the charge pump 104 further comprises a first current source 105, a second current
5 source 107, a first switch 112, and a second switch 114.

The PLL operates by maintaining charge on the first capacitor 116 of the LPF 106. A reference signal or input signal is input into the PFD 102 through a first node 122 along with feedback from the frequency divider 110 through a
10 second node 132. Based on the comparison between the inputted signals, the PFD 102 either activates the first switch 112 of the charge pump 104 through a third node 124 or activates the second switch 114 of the charge pump 104 through a fourth node 126. By activating the first switch
15 112, the charge is added to the capacitor 116 of the LPF 106 through a fifth node 128. By activating the second switch 114, charge is removed from the capacitor 116 of the LPF 106 through the fifth node 128.

The active pulling down and pulling up the charge of the
20 capacitor effectively changes the voltage of the LPF 106. The voltage of the LPF 106 is then used to control the voltage of the frequency and phase of the VCO 108. The voltage of the LPF 106 is maintained at the fifth node 128, which is input into the VCO 108. The VCO 108 then outputs
25 an output signal through a sixth node 130 that has its phase

and frequency synchronized with the input signal. The output signal from the VCO 108 is input into the frequency divider 110. Also, the output signal of VCO 108 is used in a variety of circuits to perform a variety of tasks.

5 With a conventional PLL 100 of FIGURE 1, though, there are some disadvantages. Due to the advancement of Complimentary Metal-Oxide on a Semiconductor (CMOS) technology, the resulting thickness of the dielectric of the capacitor 116 of FIG. 1 has become increasingly smaller. As
10 a result of decreasing thickness of the dielectric, there has been an increase in the leakage current across the capacitor 116 of FIG. 1. The PLL, then cannot maintain, the proper voltage for the VCO 108 of FIG. 1 resulting in drift of the locked in phase and frequency.

15 Therefore, there is a need for a method and/or apparatus for correction of leakage voltage in a PLL that addresses at least some of the problems associated with conventional methods and apparatuses for PLLs.

20 SUMMARY OF THE INVENTION

The present invention provides an apparatus for correcting charge leakage across an LPF. A voltage controlled Phased Locked Loop (PLL) is provided, wherein the PLL is at least configured to have a Low Pass Filter (LPF) and a Voltage
25 Controlled Oscillator coupled at a first node. Also, a

charge leakage correction circuit is provided that is at least coupled to the first node.

BRIEF DESCRIPTION OF THE DRAWINGS

5 For a more complete understanding of the present invention and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a block diagram depicting a conventional
10 PLL;

FIGURE 2 is a block diagram depicting an improved PLL with a charge leakage correction circuit; and

FIGURES 3a and 3b are graphs depicting the comparative operations of a PLL with and without current leakage
15 correction.

DETAILED DESCRIPTION

In the following discussion, numerous specific details are set forth to provide a thorough understanding of the
20 present invention. However, those skilled in the art will appreciate that the present invention may be practiced without such specific details. In other instances, well-known elements have been illustrated in schematic or block diagram form in order not to obscure the present invention
25 in unnecessary detail. Additionally, for the most part,

details concerning network communications, electro-magnetic signaling techniques, and the like, have been omitted inasmuch as such details are not considered necessary to obtain a complete understanding of the present invention, and are considered to be within the understanding of persons of ordinary skill in the relevant art.

It is further noted that, unless indicated otherwise, all functions described herein may be performed in either hardware or software, or some combinations thereof. In a preferred embodiment, however, the functions are performed by a processor such as a computer or an electronic data processor in accordance with code such as computer program code, software, and/or integrated circuits that are coded to perform such functions, unless indicated otherwise.

Referring to FIGURE 2 of the drawings, the reference numeral 200 generally designates an improved PLL with current leakage correction circuit. The improved PLL comprises a PFD 202, a first charge pump 204, an LPF 206, a second charge pump 252, a differentiator 250, a VCO 208, and a frequency divider 210.

The illustration of the most basic components of the improved PLL, though, do not necessarily lend to a complete explanation. The LPF 206 further comprises a capacitor 216 and a resistor 218 which operated on the principle of capacitive impedance where impedance of a capacitor is

inversely proportional to the signal frequency. Also, the first charge pump 204 further comprises a first current source 205, a second current source 207, a first switch 212, and a second switch 214. The second charge pump 252 further
5 comprises a third current source 253, a fourth current source 256, a third switch 254, and a fourth switch 255.

In a conventional PLL as depicted in FIGURE 1, though, maintaining a constant "locked" voltage can be difficult because of technological changes. Due to better and better
10 CMOS technology, the thickness of the capacitor dielectric (not shown) has decreased. As a result, current leakage across the dielectric (not shown) becomes problematic because the voltage across the capacitor 116 of FIG. 1 fluctuates. These fluctuations translate into severe short-
15 term jitter in the output characteristic of the VCO 108. The addition of correction circuitry (the second charge pump 252 of FIGURE 2 and a differentiator 250 of FIG. 2) reduces the fluctuations resulting in a clean signal.

The improved PLL operates by maintaining charge on the
20 capacitor 216 of the LPF 206. A reference signal or input signal is input into the PFD 202 through a first node 222 along with feedback from the frequency divider 210 through a second node 232. Based on the comparison between the inputted signals, the PFD 202 either activates the first
25 switch 212 of the first charge pump 204 through a third node

224 or activates the second switch 214 of the first charge pump 204 through a fourth node 226. By activating the first switch 212, the charge is added to the capacitor 216 of the LPF 206 through a fifth node 228. By activating the second
5 switch 214, charge is removed from the capacitor 216 of the LPF 206 through the fifth node 228.

The active pulling down and pulling up the charge of the capacitor effectively changes the voltage of the LPF 206. The voltage of the LPF 206 is then used to control the
10 voltage of the frequency and phase of the VCO 208. The voltage of the LPF 206 is maintained at the fifth node 228 which is input into the VCO 208. The VCO 208 then outputs an output signal through a sixth node 230 that has a phase and frequency that is synchronized with the input signal.
15 The output signal from the VCO 208 is input into the frequency divider 210. Also, the output signal of VCO 208 is used in a variety of circuits to perform a variety of tasks.

However, also attached to the fifth node 228, is a
20 second charge pump 252 and differentiator 250. While the PFD 202, first charge pump 204, and LPF 206 are in the process of achieving phase and frequency lock, the differentiator 250 remains off. Thus, initially, the second charge pump 252 and the differentiator 250 are inactive. A
25 lock detector 260 monitors the voltages of the first node

222 and the second node 232 to determine if phase and frequency lock have been achieved. Once lock is achieved, the differentiator 250 is enabled through the lock detection node 251. The differentiator 250 then monitors the voltage
5 at the fifth node 228.

In the process of monitoring the voltage at the fifth node 228, the differentiator can determine the rate of change of the voltage at the fifth node 228 with respect to time or effectively determine the derivative of the voltage
10 (dV/dt) . The derivative of the voltage (dV/dt) is proportional to the leakage current through the capacitor 216 of the LPF 206. If the rate of change of the voltage is greater than zero $(dV/dt > 0)$, then the voltage on the fifth node 228 is too high, and the fourth switch 255 of the
15 second charge pump 252 is engaged. When the fourth switch 255 is engaged, the fourth current source 256 draws current from the fifth node 228 to lower the voltage to the proper level. If the rate of change of the voltage is less than zero $(dV/dt < 0)$, then the voltage on the fifth node 228 is
20 too low, and the third switch 254 of the second charge pump 252 is engaged. When the third switch 254 is engaged, the third current source 253 supplies current to the fifth node 228 to increase the voltage to the proper level. Also, when the rate of change of the voltage is zero $(dV/dt = 0)$, then
25 the third switch 254 and the fourth switch 255 are

disengaged.

Referring to FIGURES 3a and 3b of the drawings, the reference numeral 300 generally designates graphs depicting the comparative operations of a PLL with and without current
5 leakage correction. Both FIGS. 3a and 3b voltages versus time graphs at node 228 of FIGURE 2.

In section 1 of FIGURES 3a and 3b, the first charge pump 204 of FIGURE 2 is on and the second charge pump 252 of FIG. 2 is off. During this phase of operation, the PFD 202 and
10 the first charge pump 204 of FIG. 2 are actively seeking phase and frequency lock. The PFD 202 of FIG. 2 actively engages the first switch 212 and second switch 214 of the first charge pump 204 of FIG. 2 to achieve the proper voltage at the capacitor 216 of the LPF 206 of FIG. 2.

15 In section 2 of FIGURE 3a, when lock is achieved the first charge pump 204 of FIGURE 2 is off. Also, the second charge pump 252 of FIG. 2 is off for the purposes of illustration. After phase and frequency lock have been achieved, the voltage, in section 2 of FIG. 3a, is not
20 constant. This is due to the leakage current associated with the capacitor 216 of FIG. 2.

In section 2 of FIGURE 3b, when phase and frequency lock are achieved, the first charge pump 204 of FIGURE 2 is off and the second charge pump 252 of FIG. 2 is on. The
25 second charge pump 252 of FIG. 2 actively corrects voltage

fluctuations across the LPF 206 of FIG. 2 to maintain a constant voltage. Therefore, after phase and frequency lock have been achieved, the voltage, in section 2 of FIG. 3b, is constant.

5 It will further be understood from the foregoing description that various modifications and changes may be made in the preferred embodiment of the present invention without departing from its true spirit. This description is intended for purposes of illustration only and should not be
10 construed in a limiting sense. The scope of this invention should be limited only by the language of the following claims.